CHAPTER 4 - RAINFALL AND EVAPOTRANSPIRATION

All crops need water to grow and produce yields. The most important source of water for crop growth is rainfall. When rainfall is insufficient, irrigation water may be supplied to guarantee a good harvest.

One of the main problems of the irrigator is to know the amount of water that has to be applied to the field to meet the water needs of the crops; in other words the irrigation requirement needs to be determined. Too much water means a waste of water which is so precious in arid countries. It can also lead to a rise of the groundwater table and an undesirable saturation of the rootzone. Too little water during the growing season causes the plants to wilt. Long periods during which the water supply is insufficient, result in loss of yield or even crop failure. In addition, the irrigation requirement needs to be determined for proper design of the irrigation system and for establishment of the irrigation schedules.

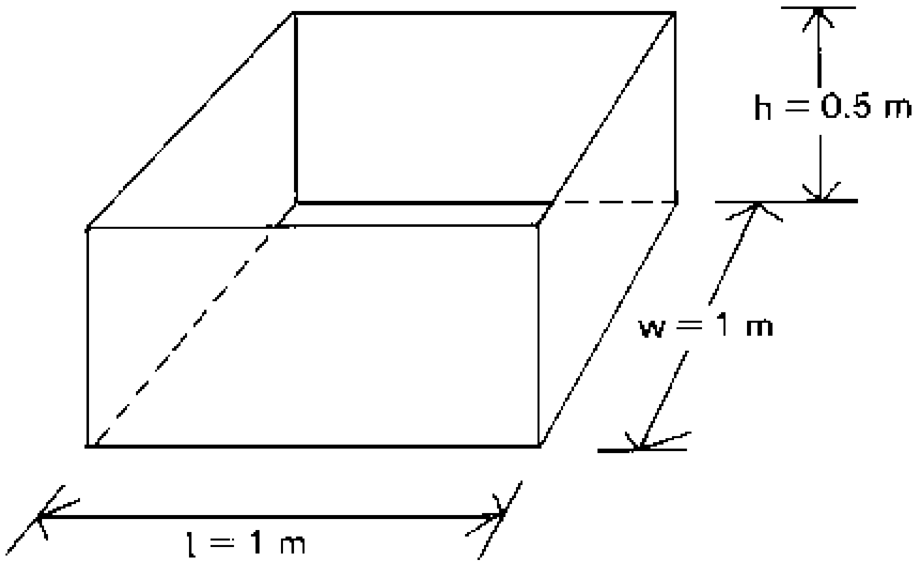
4.1 Rainfall

The primary source of water for agricultural production, for large parts of the world, is rainfall or precipitation. Rainfall is characterized by its amount, intensity and distribution in time.

4.1.1 Amount of rainfall

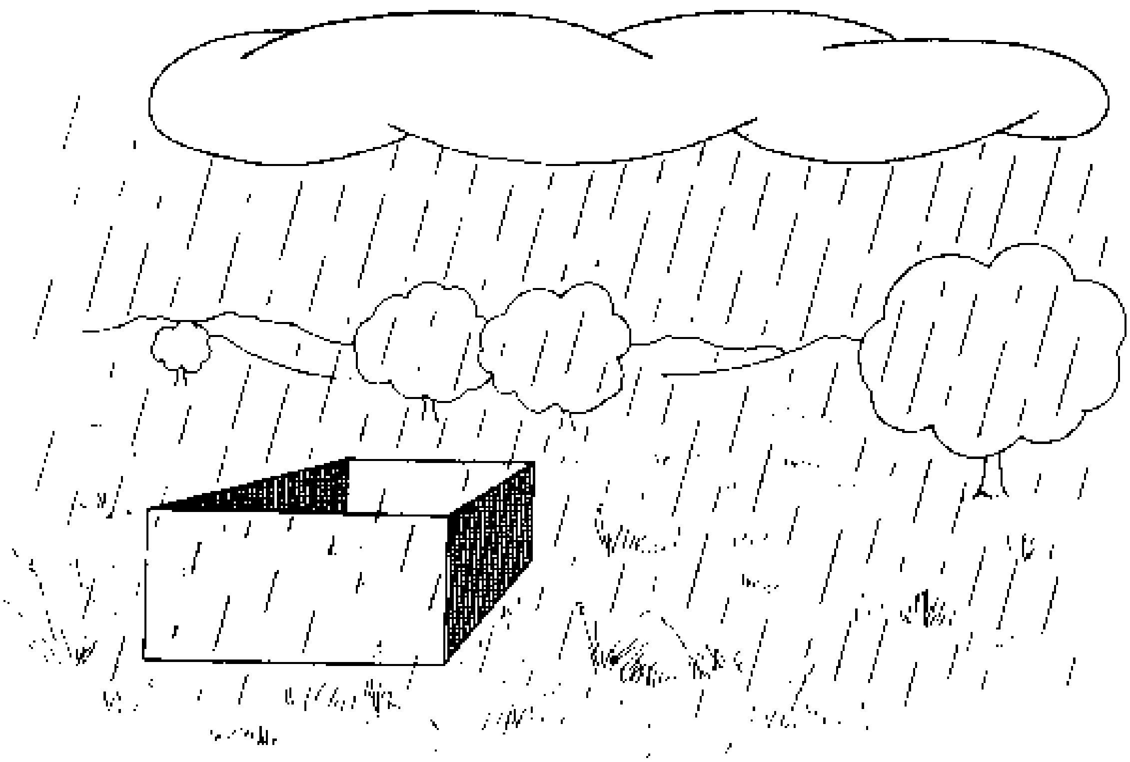
Imagine an open square container, 1 m wide, 1 m long and 0.5 m high (see Fig. 59a).

Fig. 59a. An open container to collect rainwater



This container is placed horizontally on an open area in a field (see Fig. 59b).

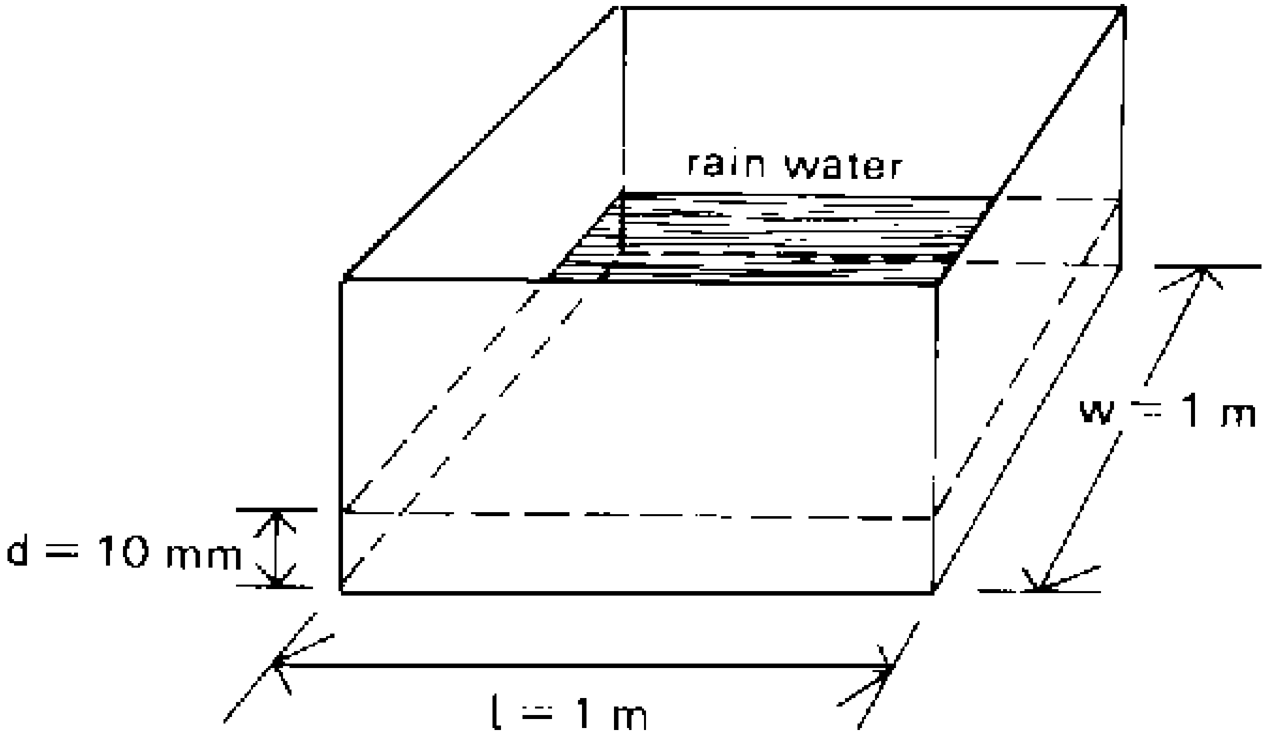
Fig. 59b. Container placed in the field



During a rain shower, the container collects the water.

Suppose that when the rain stops, the depth of water contained in the pan is 10 mm (see Fig. 59c).

Fig. 59c. 10 mm rainwater collected in the container

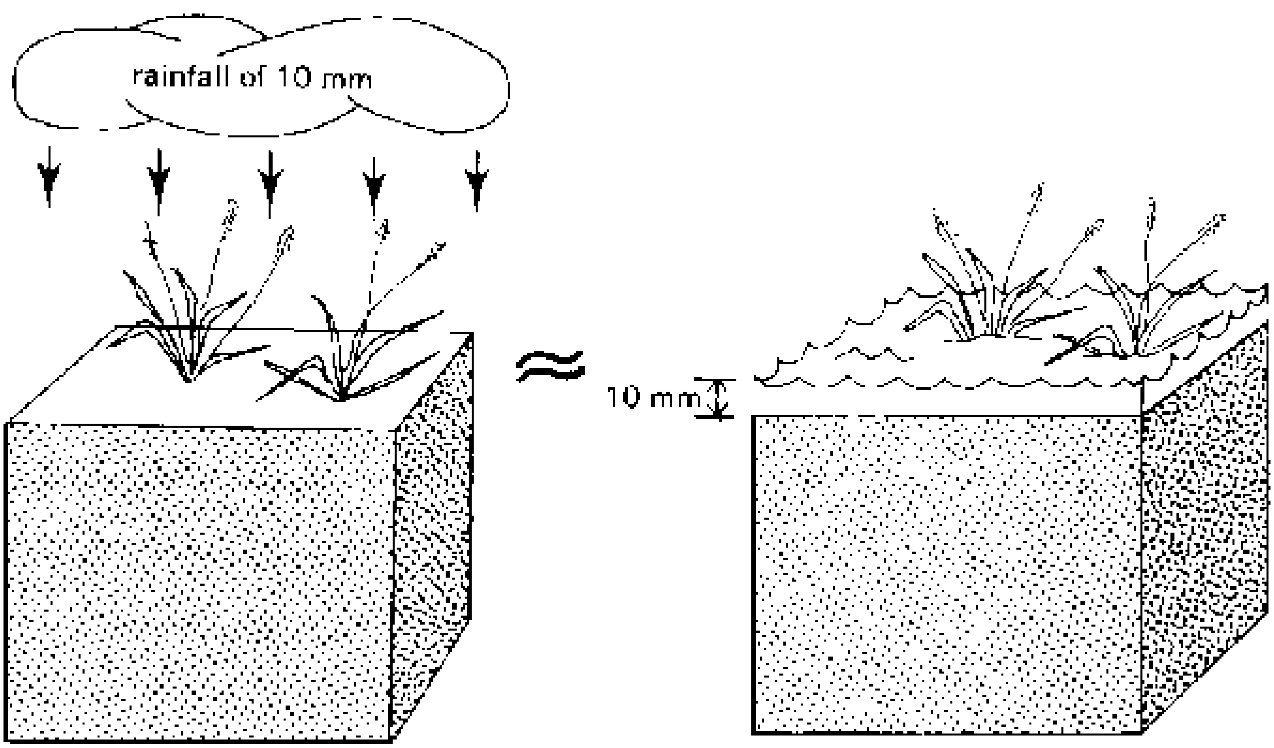


The volume of water collected in the pan is:

$V (m^3) = l (m) \times w (m) \times d (m) = 1 m \times 1 m \times 0.010 m = 0.01 m^3$ or 10 litres

It can be assumed that the surrounding field has also received an uniform water depth of 10 mm (see Fig. 59d).

Fig. 59d. 10 mm rainfall on the field



In terms of volume, with a rainfall of 10 mm, every square metre of the field receives

0.01 m, or 10 litres, of rain water. With a rainfall of 1 mm, every square metre receives 1 litre of rain water.

A rainfall of 1 mm supplies 0.001 m^3, or 1 litre of water to each square metre of the field. Thus 1 ha receives 10 000 litres.

QUESTION

What is the total amount of water received by a field of 5 ha under a rainfall of 15 mm?

ANSWER

Each hectare (10 000 m^2) receives 10 000 m^2 x 0.015 m = 150 m^3 of water. Thus the total amount of water received by the 5 hectares is: 5 x 150 m = 750 m

Rainfall is often expressed in millimetres per day (mm/day) which represents the total depth of rainwater (mm), during 24 hours. It is the sum of all the rain showers which occurred during these 24 hours.

4.1.2 Rainfall intensity

The rainfall intensity is the depth of water (in mm) received during a shower divided by the duration of the shower (in hours). It is expressed in millimetres of water depth per hour (mm/hour).

$$\text{Rainfall intensity (mm/hour)} = \frac{\text{total amount of rain water (mm)}}{\text{duration of the rainfall (hours)}} \quad \text{..... (15)}$$

For example, a rain shower lasts 3.5 hours and supplies 35 mm of water. The intensity of this shower is $\frac{35\text{ mm}}{3.5\text{ hours}} = 10\text{ mm/hour}$ (see Fig. 60).

Fig. 60. Rainfall intensity

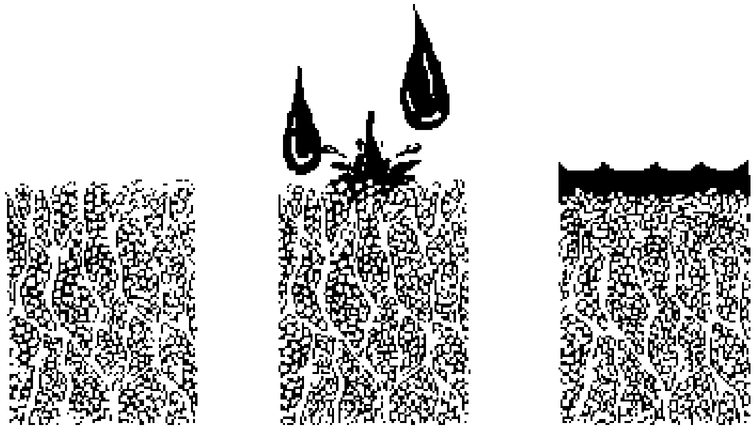
LOW INTENSITY

HIGH INTENSITY

Suppose the same amount of water (35 mm) is supplied in one hour only, thus by a shower of higher intensity: $\frac{35\text{ mm}}{1\text{ hour}} = 35\text{ mm/hour}$ (see Fig. 60).

Although the same amount of water (35 mm) has been supplied by both showers, the high intensity shower is less profitable to the crops. The high intensity rainfall usually has big drops that fall with more force on the soil surface. In fine textured soil especially, the soil aggregates break down rapidly into fine particles that seal the soil surface (see Fig. 61). The infiltration is then reduced, and surface runoff increases (see Section 4.1.4).

Fig. 61. Sealing of the soil surface by raindrops



The low intensity rainfall has finer drops. The soil surface is not sealed, the rainwater infiltrates more easily and surface runoff is limited (see Section 4.1.4).

4.1.3 Rainfall Distribution

Suppose that during one month, a certain area receives a total amount of rain water of 100 mm (100 mm/month). For crop growth, the distribution of the various showers during this month is important.

Suppose that the rainwater falls during two showers of 50 mm each, one at the beginning of the month and the other one at the end of the month (see Fig. 62a). In between these two showers, the crop undergoes a long dry period and may even wilt. Irrigation during this period is then required.

Fig. 62a. 100 mm rainfall, poorly distributed over one month

On the other hand, if the rainwater is supplied regularly by little showers, evenly distributed over the month (see Fig. 62b), adequate soil moisture is continuously maintained and irrigation might not be required.

Fig. 62b. 100 mm rainfall, evenly distributed over one month

Not only the rainfall distribution within a month is important. It is also important to look into the rainfall distribution over the years.

Suppose that in a certain area the average rainfall in May is 150 mm and that this amount is just sufficient to satisfy the water need of the crops during this month. You may however find that, in this area, the rainfall in an exceptionally dry year is only 75 mm, while in a wet year the rainfall is 225 mm. In a dry year it would thus be necessary to irrigate the crops in May, while in an average year or a wet year, irrigation is not needed.

4.1.4 Effective Rainfall

i. Introduction

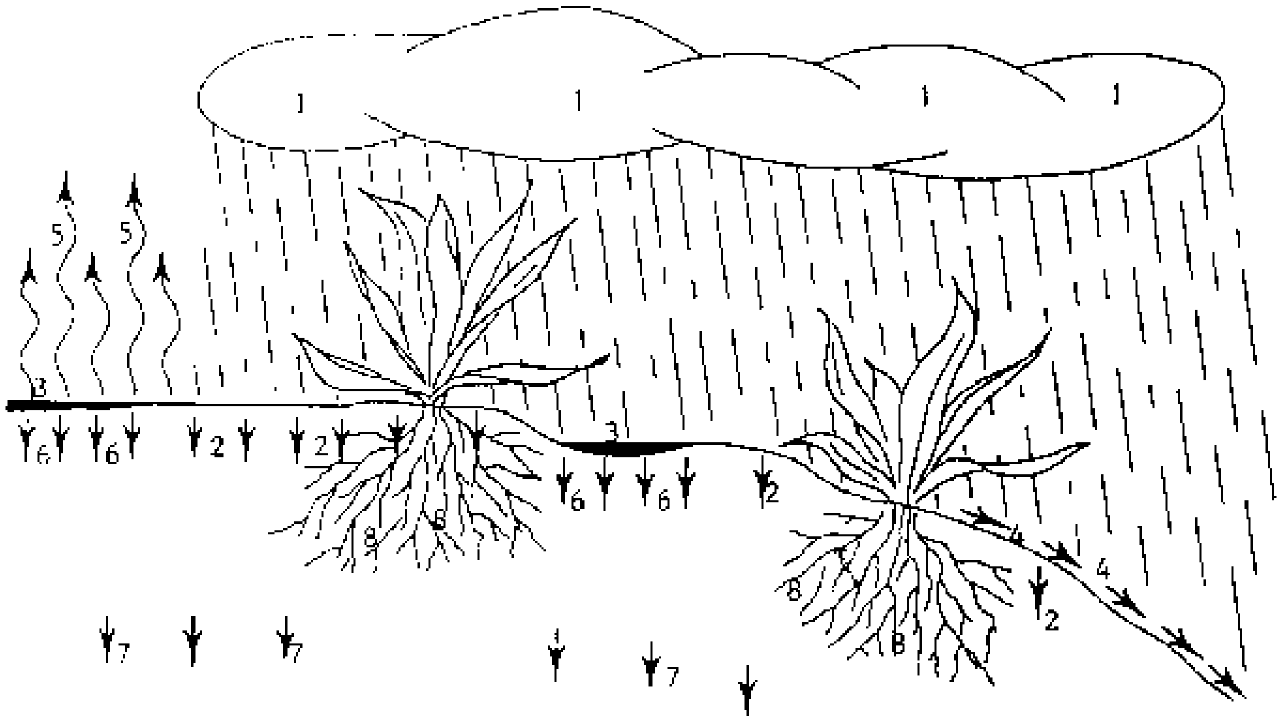
When rain water ((1) in Fig. 63) falls on the soil surface, some of it infiltrates into the soil (2), some stagnates on the surface (3), while some flows over the surface as runoff (4).

When the rainfall stops, some of the water stagnating on the surface (3) evaporates

to the atmosphere (5), while the rest slowly infiltrates into the soil (6).

From all the water that infiltrates into the soil ((2) and (6)), some percolates below the rootzone (7), while the rest remains stored in the rootzone (8).

Fig. 63. Effective rainfall (8) = (1) - (4) - (5) - (7)



In other words, the effective rainfall (8) is the total rainfall (1) minus runoff (4) minus evaporation (5) and minus deep percolation (7); only the water retained in the root zone (8) can be used by the plants, and represents what is called the effective part of the rainwater. The term effective rainfall is used to define this fraction of the total amount of rainwater useful for meeting the water need of the crops.

ii. Factors influencing effective rainfall

Many factors influence the amount of the effective rainfall. There are factors which the farmer cannot influence (e.g. the climate and the soil texture) and those which the farmer can influence (e.g. the soil structure).

a. Climate

The climate determines the amount, intensity and distribution of rainfall which have direct influence on the effective rainfall (see 4.1.3 and 4.1.4).

b. Soil texture

In coarse textured soil, water infiltrates quickly but a large part of it percolates below the rootzone. In fine textured soil, the water infiltrates slowly, but much more water is kept in the rootzone than in coarse textured soil.

c. Soil structure

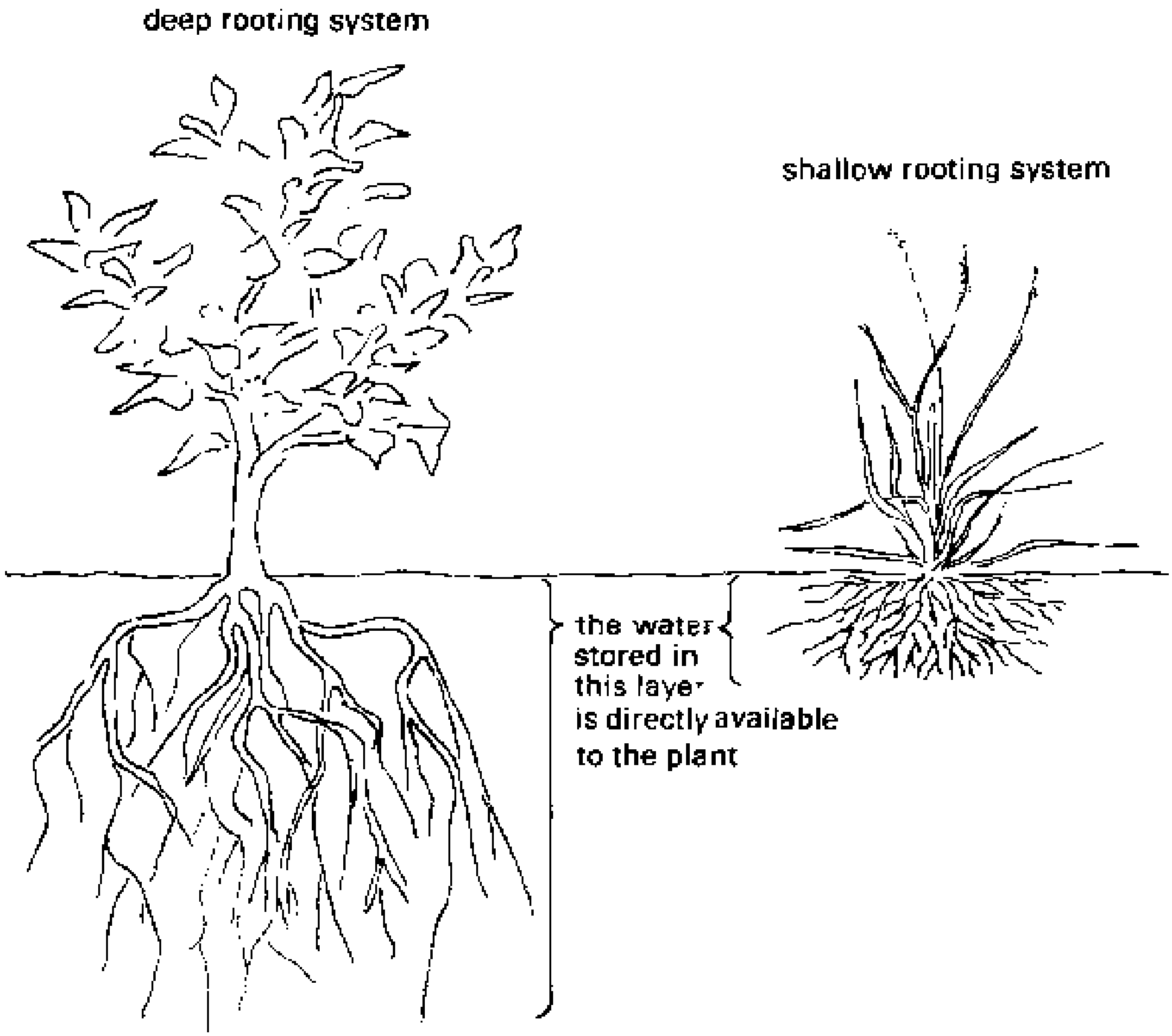
The condition of the soil structure greatly influences the infiltration rate

and therefore the effective rainfall. A favourable soil structure can be obtained by cultural practices (e.g. ploughing, mulching, ridging, etc.).

d. Depth of the rootzone

Soil water stored in deep layers can be used by the plants only when roots penetrate to that depth. The depth of root penetration is primarily dependent on the type of crop, but also on the type of soil. The thicker the rootzone, the more water available to the plant. (see Fig. 64).

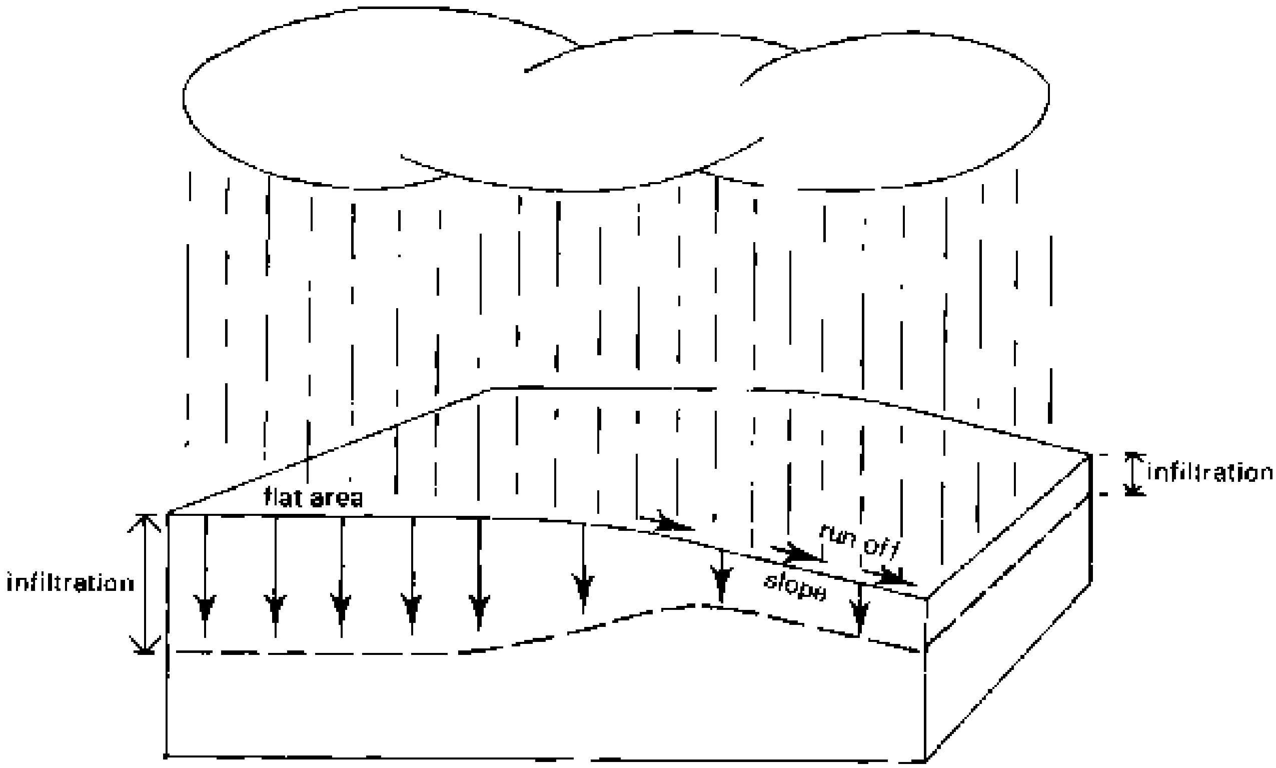
Fig. 64. Effective rainfall and depth of the rootzone



e. Topography

On steep sloping areas, because of high runoff, the water has less time to infiltrate than in rather flat areas (see Fig. 65). The effective rainfall is thus lower in sloping areas.

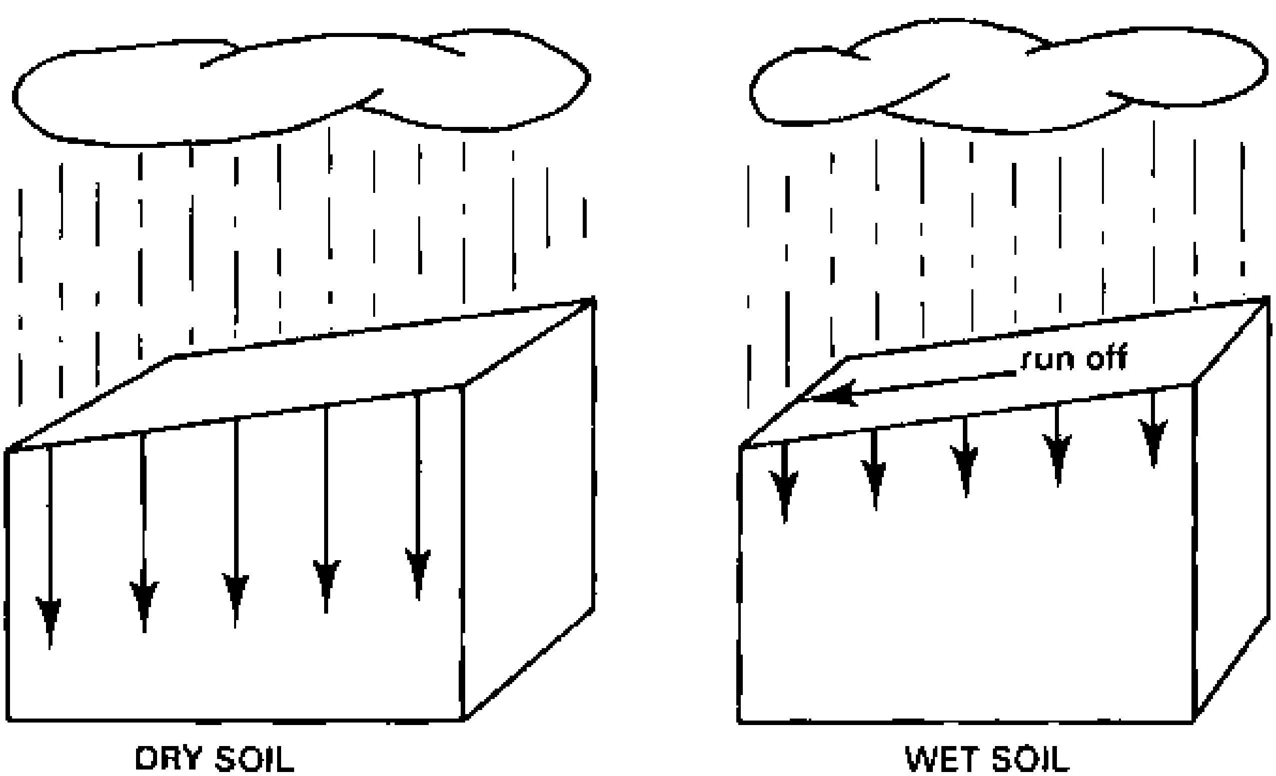
Fig. 65. Effective rainfall and topography



f. <u>Initial soil moisture content</u>

Chapter 2.2.3 ii, explained that for a given soil, the infiltration rate is higher when the soil is dry than when it is moist. This means that for a rain shower occurring shortly after a previous shower or irrigation, the infiltration rate is lower and the surface runoff higher (see Fig. 66).

Fig. 66. Effective rainfall and initial soil moisture content



g. Irrigation methods

There are different methods of irrigation which will be explained in Chapter V, and each method has a specific influence on the effective rainfall.

In basin irrigation there is no surface runoff. All the rainwater is trapped in the basin and has time to infiltrate (Fig. 67a).

In inclined border and furrow irrigation, the runoff is relatively large. At the lower end of the field the runoff water is collected in a field drain and carried away (Fig. 67b). Thus the effective rainfall under border or furrow irrigation is lower than under basin irrigation.

In contour furrow irrigation there is very little or no slope in the direction of the furrow and thus runoff is limited; the runoff over the cross slope is also limited as the water is caught by the ridges. This results in a relatively high effective rainfall, compared to inclined border or furrow irrigation (see Fig. 67c).

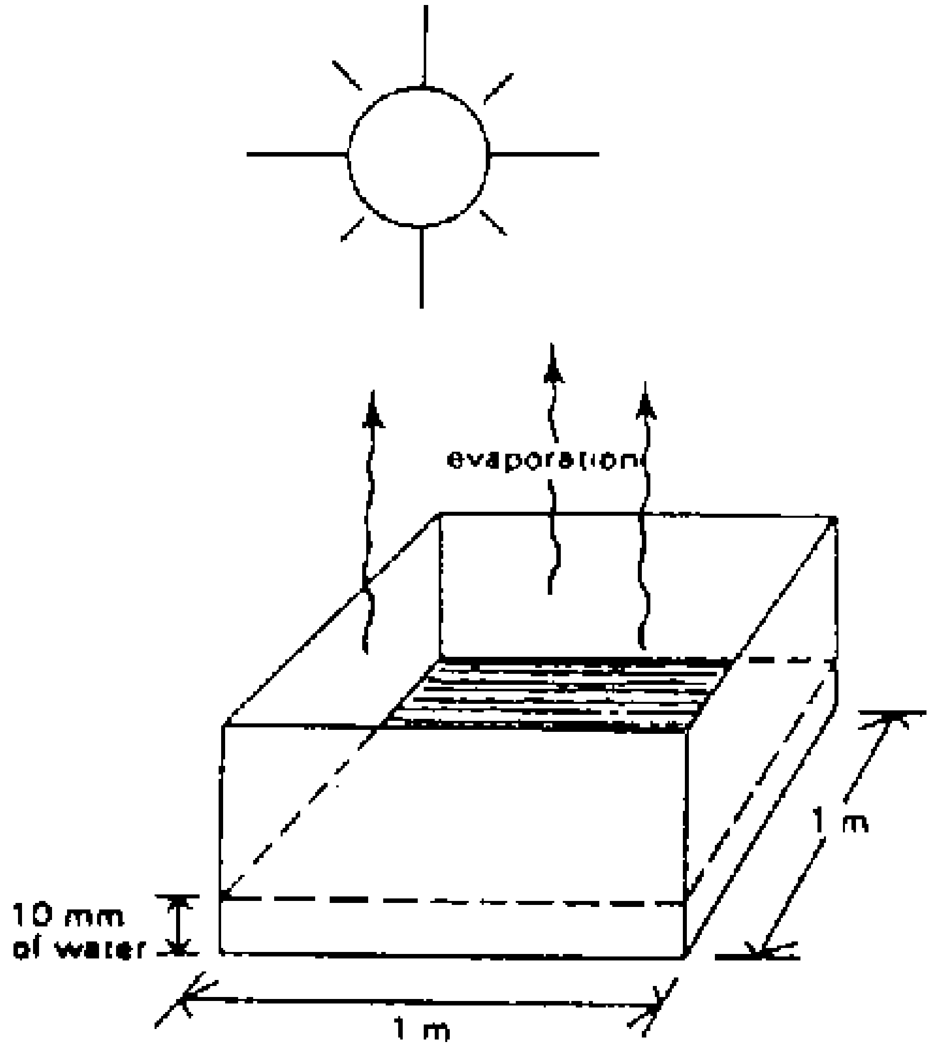
Fig. 67a + b + c. Effective rainfall and irrigation methods

4.2 Evapotranspiration

4.2.1 Evaporation

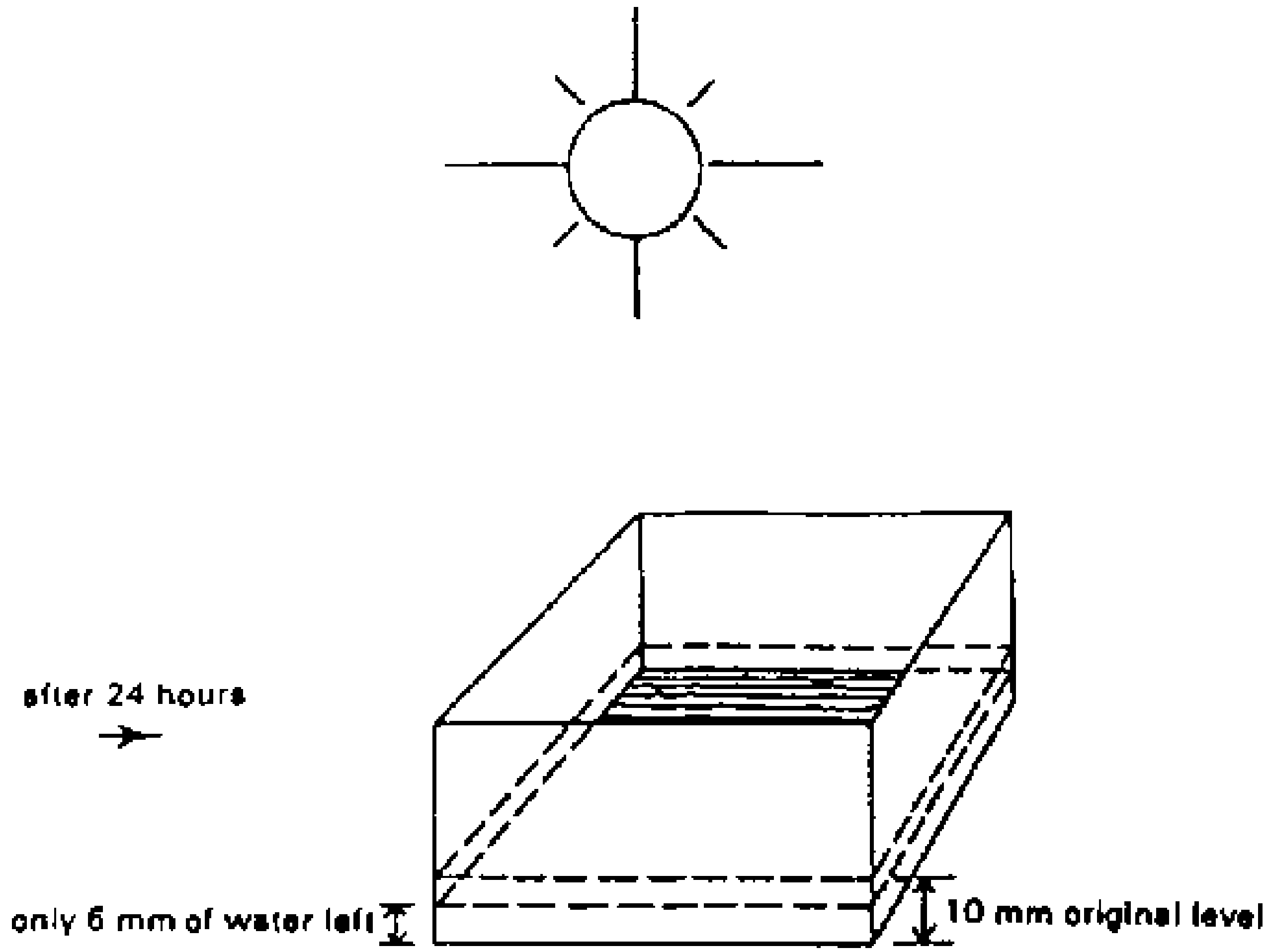
Imagine the same open container (Section 4.1.1) as used for the collection of rain water, but this time with a depth of 10 mm of water in it; leave the container in the field for 24 hours. Make sure that it does not rain during those 24 hours (Fig. 68a).

Fig. 68a. Container with 10 mm of water



At the end of the 24 hours, part of the water originally in the container has evaporated. If only 6 mm of water depth remains in the container, then the evaporation during this day was 10 - 6 = 4 mm (see Fig. 68b).

Fig. 68b. After 24 hours, 6 mm of water is left in the container



Some water from the soil in the field surrounding the container has also evaporated during the day. But it would be wrong to assume that the evaporation from the container is the same as the evaporation from the soil.

In fact, evaporation from the soil surface is at most equal but usually considerably less than evaporation from an open water surface.

4.2.2 Transpiration

The plant roots suck or extract water from the soil to live and grow. The main part of this water does not remain in the plant, but escapes to the atmosphere as vapour through the plant's leaves and stems. This process is called transpiration of the plant.

Transpiration happens mainly during the day time.

The amount of water used by the plants for transpiration can, like evaporation, be expressed in millimetres of water per day (mm/day). Note that a day has 24 hours.

4.2.3 Evapotranspiration

The evapotranspiration of a crop is the total amount of soil water used for transpiration by the plants and evaporation from the surrounding soil surface.

In other words, the crop evapotranspiration represents the amount of water utilized by the crop and its environment.

The evapotranspiration is commonly expressed in millimetres of water used per day (mm/day) or per week (mm/week) or per month (mm/month).

4.2.4 Factors influencing crop evapotranspiration

Many factors influence the evapotranspiration of the crop. The main ones and their effects are shown in the following table.

Factor	**Effect on crop evapotranspiration**	
	high	**low**
Climate	hot	cool
	dry	wet
	windy	no wind
	no clouds	cloudy
Crop	mid/late season	initial or ripening
	dense plant spacing	wide plant spacing
Soil moisture	moist	dry